REMARKS

First, it is noted that the Examiner indicated the allowability of claims 3, 5, 8, and 10-14, if rewritten to overcome rejections on formal matters. It is believed that the amendments to the claims in this reply overcome those rejections so these claims are now allowable. The Examiner will note that original Claim 3 was multiple dependent, depending from Claims 1 or 2. Claim 3 is now independent and new Claim 15, depending from Claim 3, is the same as original Claim 2.

The Examiner required that figures 20-24 be designated as "Prior Art". A separate letter to the Official Draftsman is being submitted herewith requesting approval of amendment to those figures.

The Examiner also required that the contact angle be shown in the drawings. While Applicants believe this should be unnecessary, they are adopting the Examiner's suggestion and are submitting a new Fig. 25 showing this feature. The specification is also being amended to describe the new Fig. 25.

The Examiner objected to the Abstract because it is longer than 150 words. A new Abstract on a separate sheet in being submitted herewith.

The Examiner rejected claims 1-7 and 11-14 under 35 U.S.C. §112, first paragraph, as containing subject matter which was not described in the specification in such a way as to enable one skilled in the art to make and/or use the invention. The Examiner said that the claimed "contact angle" is not described or illustrated. With the proposed drawing amendment, it is illustrated. In fact, it is described in the instant specification at page 65, line 14,

- page 69, line 22. In addition, the specification has been amended to refer to new figure 25.

The Examiner rejected claims 1-14 under 35 U.S.C. §112, second paragraph, as being indefinite. In claims 1, 8, 9, and 10, the Examiner considered the phrase "selectively having a cage" to be indefinite. While Applicants do not agree, the claims have been amended to change "selectively" to –optionally--.

The Examiner said that claims 1-14 are "replete with the alternative form 'or' which make [sic.] them indefinite." This ground of rejection is respectfully traversed. The Examiner's attention is directed to Section 2173.05(h) of the MPEP, Section II which says "alternative expressions using 'or' are acceptable". That section of the MPEP goes on to give examples of acceptable alternative terminology. The Examiner is, therefore, respectfully requested to withdraw this ground of rejection.

The Examiner questioned the word "obstacles" in claim 6 and "a layer of harness" in claim 7. Claim 6 has been amended to change "obstacles" to --particles--. The Examiner is correct that this was a literal translation. As far as claim 7 is concerned, the word "harness" does not appear in claim 7. It is assumed that the Examiner was referring to "a layer of a hardness higher than that of the raceway surface". The Examiner will note that this has been changed to --layer having a hardness higher than that of the raceway surface--. It is believed this ground of rejection is now moot.

The Examiner rejected claims 1, 2, and 7 under 35 U.S.C. §103(a) as unpatentable over Wallin in view of Kinno, et al. The Examiner contended that

Wallin shows a roller bearing comprising an outer ring, an inner ring, and rolling elements with a contact angle of 30°. Wallin is silent on how the bearing is lubricated. Kinno, et al. Teach the concept of using PTFE to lubricate bearings. The Examiner concluded it would have been obvious to have considered using PTFE as a lubricant for Wallin's bearing. This rejection is respectfully traversed.

Wallin discloses a screw compressor assembly which comprises a housing, a pair of rotors rotatably journaled in the housing, a bearing system supporting the rotors including a radial cylindrical roller bearing and thrust bearing means rotatably supporting the journals in the housing, including:

> a first angular contact thrust ball bearing having a predetermined contact angle in the range of between about 30° and 35°, and
>
> a second back-up angular contact bearing having a contact angle less than the contact angle of the first thrust bearing and in the range of between about 15° and 20°,
>
> the difference between the contact angles of the thrust bearing and backup bearing being at least between about 10° and 20°,

whereby the internal force due to centrifugal force is small and therefore the induced axial force in the bearing system is minimized (as compared with the rolling bearing having the same contact angle).

Kinno et al. disclose a roller bearing in which surface layers are formed on the inner surfaces of flanges which confront with the end faces of cylindrical rollers and the surface layers contain solid lubricant (MoS2, PTFE, or a mixture of them, column 3, lines 16-17). Hence, even when the roller bearing is

insufficiently lubricated, the temperature rise is effectively suppressed. Then, in the taper roller bearing as shown in the third and fourth examples, it is disclosed that the contact angle is 16° and the conical angle of each taper roller is 1°55' (column 5, lines 20-23).

Wallin's bearing is an assembly for use in screw compressors for supporting rotors during high speed rotation, and has as a main feature that the contact angle for a first angular ball bearing near rotor is 30° to 35°, and the contact angle for a second back-up angular ball bearing is 15° to 30°. The effect of the combination is to minimize the induced axial force in the bearing system due to the centrifugal force acting on the rotors or balls.

However, Wallin is used in so called "Dry Air Screw Compressors" as described in column 1, lines 18 to 21, and the bearing for dry air screw compressors does not use lubricants (hereafter, called as "fluoro-lubricant" in this invention) such as lubricating oil or greases containing fluoro-containing polymers according to the present invention.

On the other hand, the present invention relates to a rolling bearing which is used in a reduced pressure atmosphere or in a high temperature circumstances and the fluoro-lubricant is used as a precondition in the present invention. The fluoro-lubricant has the following features:

(1) it satisfies the requirement for preventing contamination and has a high corrosion resistance and is less evaporative in reduced pressure atmosphere,

(2) it is excellent in heat resistance, less evaporative and chemically stable in high temperature circumstance.

However, there is a problem to be solved in the fluoro-lubricant as follows:

(3) since the fluoro-lubricant (e.g. fluoro-lubricating oil) has a higher specific gravity and has poor wettability on a metal surface such as raceway surfaces of an inner ring, outer ring and rolling surface of a rolling element, the lubricating oil does not collect in small gaps, particularly at a high speed rotation and in a reduced pressure atmosphere.

In addition to such a severe lubricating condition with the fluoro-lubricant, if the surface roughness of the rolling surface of the rolling element and the raceway surfaces of the inner and outer rings deteriorate initially, or the surface roughness worsens by wear and foreign matter, it tends to cause peeling wear or peeling flaking.

Further, if the temperature becomes higher, the fluoro-lubricating oil reacts with iron to form iron fluorides, and iron fluorides act as a catalyst to decompose the fluoro-lubricating oil. Particularly, when the lubrication is insufficient, and the rolling surface of the rolling element and the raceway surface of the bearing ring are in direct contact with each other, the contact point is locally heated to an extremely high temperature, this high temperature decomposes the fluoro-lubricating oil (PFPE oil and the like) to erode the surfaces of the rolling element, the bearing ring and the cage.

Moreover, when silicon nitride (Si_3N_4) is used for rolling elements, it causes "another problem or negative problem" that the PFPE oil reacts with Si due to locally high temperature as described above, as a result, Si_2F_6 gas is evolved to embrittle material and result in abnormal wear.

It is thought that the contact between the rolling surface and the raceway surface of the bearing ring is performed on the contact surface which has uneven surface formed by surface roughness and the maximum temperature at the contacting point exceeds 700°C (see Reference 1 attached hereto, "An introduction to tribology" (published by Yohkendoh in 1984).

As described under the heading "Temperature Elevation on Frictional Surface" at page 151, lines 9 to end and in page 153, line 1 of Reference 1, the maximum temperature elevation observed by Bowden and Ridler exceeds 700°C, regarding various kinds of metals by changing the sliding speed. Results are not so different in every metal. Such a generation of a high temperature is not only seen in a case of so-called dry friction, but also in a case where a fatty acid is used as a lubricant (the temperature elevation of several hundred degrees). In either case, although a metal itself looks cold, locally a very high temperature is generated in the metal.

Although this proof explains about the frictional surface, even if the lubricant exists, it can be estimated easily that a maximum temperature exceeding 700°C is locally generated at the actual contacting point where a sliding occurs on the rolling surfaces of this invention.

Further, the heat decomposition temperature for the fluoro-containing polymer which is the fluoro-lubricant of the present invention is shown in Table 3 "Thermal characteristics of fluoro-resin" of "Engineering Plastics (published by Plastics Eng. Co., Ltd., on May 10, 1984) attached hereto as Reference 2.

The heat decomposition temperature of PTFE is 508° to 538°C. If a temperature of 700° C or more is generated at the actual contacting point as

described above, "a negative problem" as mentioned above and also clearly explained in the instant specification, then PTFE decomposes.

As discussed above, the present invention solves a peculiar problem that sliding occurs under severe lubricating conditions with a fluoro-lubricant.

Although Wallin discloses that two kinds of angular ball bearings are used and the contact angles of the two angular ball bearings overlap those of the present invention, Wallin does not teach the fluoro-lubricant which is the subject matter of this invention. Rather, air is used as the lubricant as it is a "Dry Air Screw Compressor" (as discussed above). On the other hand, as shown in the instant Claims 1, 2 and 7, the requirements for use of fluoro-lubricant are indispensable and the difference or the fault can be interpreted by the contact angle relation. Wallin invention involves a different idea, in which two kinds of angular ball bearings having different contact angles are combined in order to reduce the axial force.

Further, a contact angle of 10° to 45° (preferably 15° to 30°) is critical to the present invention as shown in Table 10 and Fig. 7, based on the results of tests which were performed under high temperature and high pressure with fluoro-lubricating oil, and the peeling flaking is suppressed without reducing loading capacity.

Kinno et al. discloses a roller bearing in which surface layers are formed on the inner surfaces of flanges which confront with the end faces of cylindrical rollers and the surface layers contain solid lubricant (PTFE, MoS_2 or a mixture of them). The contact angle of the taper roller bearing is 16°. Hence, even when

the roller bearing is insufficiently lubricated, the temperature rise is effectively suppressed.

The solid lubricant layer of Kinno et al. (mentioned in this invention as the conventional technology) is formed as follows: (column 4, lines 11 to 21).

Firstly, the inner surface of the flanges 15 and 16 were subjected to phosphating, and then a polyamideimide DMF solution, in which PTFE particles were dispersed, was sprayed on the inner surface thus processed to a thickness of 10□m, to form DMF solution layers on them. Finally, the resultant polyamideimide resin on the inner race 5a and the outer race 7a was thermally set at a temperature of 180°C.

Similarly, the formation of a MoS_2 layer is described in column 4, lines 26 to 32 and column 5, lines 55 to 60.

The surface layer of solid lubricant of Kinno et al. is not used in an operating condition in which metal contact occurs due to the sliding which is the target of this invention. Its function is to completely avoid metal contact, even when lubrication is insufficient or drained, in order to not cause metal contact (like the prior art).

On the other hand, since the fluoro-lubricant is used in the present invention, and has the specific features as follows:

(1) the fluoro-lubricant of the present invention is not used in a fixed state like the surface layer of solid lubricant of D2 and It may flow into the pocket of cage, ball and rolling surface even if it's fluidity is poor.

(2) since the fluoro-lubricant of the present invention is enclosed in a rolling bearing as a lubricant, many and complicated processes for forming the surface layer of D2 are not needed.

(3) since the thickness of the lubricating oil of the present invention is not enough to reduce a bearing clearance like Kinno, it differs from the solid lubricant of Kinno et al.

In summary, Wallin does not disclose or suggest a combination of the fluoro-lubricant of this invention and the contact angle of the balls of the bearing. Further, Kinno et al. do not use the fluoro-lubricant of this invention and the contact angle of the Kinno et al. balls differs from that of this invention. Still further, Kinno et al. disclose only a taper roller bearing. Therefore, the Kinno et al. reference, like Wallin, does not teach the idea that a fluoro-lubricant is used and the problems accompanied with use of the fluoro-lubricant is to be solved by preventing spin sliding and without reducing load capacity.

The Examiner rejected claim 4 under 35 U.S.C. §103(a) as unpatentable over Wallin in view of Kinno, et al. and further in view of Tanaka et al. Tanaka et al. is cited for a teaching of the steel alloy composition of the balls. This rejection is respectfully traversed.

Tanaka et al. disclose a rolling device which includes an outer member, an inner member and a plurality of rolling elements and at least one of the outer member, inner member and rolling element is formed of an alloy steel containing:

C of 0.6 wt% or less; Cr of 10.0 to 22.0 wt%; Mn of 0.1 to 1.5 wt%; Si of 0.1 to 2.0 wt%; N of 0.05 to 0.2 wt%; Mo of 0 to 3.0 wt%; V of 0 to 2.0 wt%.

At the same time, the eutectic carbides contained in the composing steel material have a major diameter of 20 □m or less and the surface hardness is an H_RC of 58 or more and the amount of retained austenite is 6 vol% or less. In addition, the content of C and N are set for 0.6 wt% or less and 0.05 to 0.2 wt%, respectively from the viewpoint of increasing the corrosion resistance and the solubility (upper limit) of nitrogen under the atmospheric pressure. Thus, the rolling device has excellent characteristics in fatigue strength, wear resistance, corrosion resistance and acoustic characteristics.

Although Tanaka et al. disclose a rolling device that overlaps the content of Cr (%) of the present invention and has high corrosion resistance, they do not teach the use of a fluoro-lubricant, like Wallin and Kinno et al.

As discussed above, the basic combination of Wallin and Kinno et al. would not have lead one of ordinary skill in the art to the instant invention as claimed in Claims 1, 2, and 7. The Tanaka et al. reference does not cure the defects of the combination of Wallin and Kinno et al.

The Examiner rejected claim 6 under 35 U.S.C. §103(a) as unpatentable over Wallin in view of Kinno, et al. and further in view of Niizeki. Niizeki is cited for the idea of having a raceway surface without impurity particles of mean diameter of 3 μm or more. This rejection is respectfully traversed.

Niizeki discloses a rolling bearing which comprises an outer ring, an inner ring, rolling elements made of ceramics (Si_3N4, Sic, Al_2O_3 and ZrO_2 etc.) and retainer and the surface roughness of the respective raceway surfaces of the outer ring and the inner ring are set in the range of 0.1 and 3.2 □m Ra (in order to vibrate the rolling elements suitably and to provide an opportunity to contact

with the rolling elements from the self-lubricating retainer and to perform shift adhesiveness of solid lubricant onto the rolling bodies in the range to which vibration does not become excessive). Since the retainer is made of self-lubricating material such as PTFE, ETFE and PFA etc., the rolling bearing can be used under an environment such as in vacuum, high temperature, corrosive gas and the like.

The subject matter of claim 6 is that foreign matter with a mean diameter in excess of 3m is not present at least on the raceway surface of the outer ring and the inner ring.

The retainer of Niizeki has a frictional mechanism similar to the solid lubricant of Kinno et al., but compared with the fluoro-lubricant of this invention, the solid lubricant of Niizeki is supplied to the required location by shift adhesiveness and is not quick-acting.

Moreover, although the Examiner cited Niizeki for a teaching of the concept of having a raceway surface without foreign matter of mean diameter of 3 m or more, the reference only teaches that the surface roughness of the raceway surfaces of the outer ring and the inner ring are set in the range of 0.1 to 3.2 m Ra. Indeed, there is no statement or teaching of the concept in the abstract and the specification of Niizeki of having a raceway surface without foreign matter of mean diameter of 3 m or more.

The Examiner rejected claim 9 under 35 U.S.C. §103(a) as unpatentable over Niizeki in view of Yasui et al. and Masuda et al. This rejection is respectfully traversed.

Niizeki has already been discussed. Yasui et al. disclose a bearing device for a dental hand piece which is equipped with a rotary shaft with a fixed turbine blade, ball bearings engaged in the rotary shaft at both sides of the turbine blade and a housing supporting the ball bearings and a holder for the ball bearings. The holder for the bearings is a crown type holder in which pockets for holding a ball are formed on one side of a synthetic resin cylinder with a fiber layer (made from a pipe material made of a phenol resin within cloth) formed inside and a chamfer part is formed on the side end face of the pocket opening. The fiber layer of the holder is impregnated with lubricating oil. The bearing device has a small centrifugal force due to the reduction in weight of the chamfer part and can reduce the abrasion and the torque.

Masuda et al. disclose a ball bearing which includes a ball retainer having grease feeding holes which extend toward the balls and is used to support a head and carriage assembly of a data disk apparatus and the like. In the ball bearing by Masuda et al., Grease is fed only to those balls which actually need lubrication, and no remaining grease flows into a gap between the inner race or the outer race and the ball retainer, therefore frictional force does not increase.

These three references do not disclose the subject matter that the fluoro-lubricant used in this invention at all. The main features are listed below:

(a) In Niizeki, the retainer is made of PTFE

(b) The cage of this invention is made by applying chamfering to inner and outer diametrical sides of the pocket in order to make ingress of lubricating oil easy. The chamfer part of Yasui et al. is a slope surface for reducing centrifugal force and sacrifices holding the ball of the pocket.

(c) Masuda et al. disclose that there is a through hole in the bottom of the pocket.

However, Niizeki, Yasui et al., and Masuda et al. do not teach that a cage is made excellent in heat resistance and chemical resistance by combining the features (a) to (c) above. Particularly, these references do not disclose a combination of a chamfer making lubricating oil pass into the pocket of the cage easy, and a through hole.

Additionally, these references do not teach the concept of the fluoro-lubricant upon which the present invention is based.

Accordingly, it is respectfully submitted that the references as applied by the Examiner do not teach the instant invention claimed in Claims 1, 2, 4, 6, 7, and 9.

Since all the claims are clearly in condition for allowance and distinguish over the prior art of records, whether taken singly or in combination, an early Notice of Allowance is in order and the same is most earnestly solicited.

If there are any questions regarding this amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket #313MC/49472).

Respectfully submitted,

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APPENDIX

IN THE SPECIFICATION

Page 33, after the last line, insert the following new paragraph:

--Fig. 25 is a longitudinal cross sectional view illustrating the embodiment of the present invention which is also shown in Fig. 7.--

Page 68, between lines 11 and 12, insert the following new paragraph:

--Fig. 25 shows the full complement angular ball bearing having a contact angle α from 10 to 45°, preferably from 15° to 30°.--

IN THE CLAIMS

Please amend Claims 1-3, 5-10, and 12-14 as follows:

--1. (Twice amended) A rolling bearing comprising at least an outer ring having an outer ring raceway, an inner ring having an inner ring raceway, and rolling elements rotatably disposed between the outer ring raceway and the inner ring raceway, and [selectively] optionally having a cage for evenly distributing the rolling elements in the rotational direction of the rolling elements between the outer ring raceway and the inner ring raceway, and used under lubrication with a lubricating oil or a grease containing a fluoro-containing polymer, or in an atmosphere containing a gas comprising fluorides, wherein the bearing comprises ball [bearing] bearings with a contact angle [being] from 10° [or more and] to 45° [or less].

2. (Amended) The rolling bearing as defined in claim 1, wherein the contact angle is from 15° [or more] to 30° [or less].

3. (Amended) [The rolling bearing as defined in claim 1 or 2,] A rolling bearing comprising at least an outer ring having an outer ring raceway, an inner ring having an inner ring raceway, and rolling elements rotatably disposed between the outer ring raceway and the inner ring raceway, and optionally having a cage for evenly distributing the rolling elements in the rotational direction of the rolling elements between the outer ring raceway and the inner ring raceway, and used under lubrication with a lubricating oil or a grease containing a fluoro-containing polymer, or in an atmosphere containing a gas comprising fluorides, wherein the bearing comprises ball bearings with a contact angle from 10° to 45°, wherein the raceway surface roughness of the outer ring and the inner ring is 0.05 μm Ra [and] or less or the ratio of the raceway surface roughness of the outer ring or the inner ring relative to the surface roughness of the rolling element is 6 or less.

5. (Twice amended) [The rolling bearing as defined in claim 1 or 2,] A rolling bearing comprising at least an outer ring having an outer ring raceway, an inner ring having an inner ring raceway, and rolling elements rotatably disposed between the outer ring raceway and the inner ring raceway, and optionally having a cage for evenly distributing the rolling elements in the rotational direction of the rolling elements between the outer ring raceway and the inner ring raceway, and used under lubrication with a lubricating oil or a grease containing a fluoro-containing polymer, or in an atmosphere containing a gas comprising fluorides, wherein the bearing comprises ball bearings with a

contact angle from 10° to 45°, wherein at least the rolling element comprises oxide ceramics or has a dense nitride layer on the rolling surface of the rolling element, and the rolling surface roughness of the rolling element, and the surface roughness of the rolling element is 0.005 μm Ra or less and the rolling surface [harness] hardness is Hv 900 or more.

6. (Amended) The rolling bearing as defined in claim 1 or 2, wherein [obstacles] particles with a mean diameter in excess of 3 μm are not present at least on the raceway surface of the outer ring and the inner ring.

7. (Amended) The rolling bearing as defined in claim 1 or 2, wherein a hard layer [of] having a hardness higher than that of the raceway surface of the outer ring and the inner ring is coated at least to the rolling surface of the rolling element.

8. (Amended) A rolling bearing comprising an outer ring having an outer ring raceway, an inner ring having an outer ring raceway, and rolling elements rotatably disposed between the outer ring raceway and the inner ring raceway, and [selectively] optionally having a cage for evenly distributing the rolling elements in the rotational direction of the rolling elements between the outer ring raceway and the inner ring raceway, and used under lubrication with a lubricating oil or a grease containing a fluoro-containing polymer or in an atmosphere containing a gas comprising fluorides, wherein

the cage is formed with an advanced resin material into a circular shape, a plurality of pockets each containing the rolling element through an opening and rotatably holding the same are disposed at a predetermined distance in the circumferential direction, the size for the opening of a pocket having a weld line has a value of 93% or more for the diameter of the rolling element, and the size for the opening of at least two other pockets is 80% or more and 93% or less for the diameter of the rolling element.

9. (Amended) A rolling bearing comprising an outer ring having an outer ring raceway, an inner ring having an outer ring raceway, and rolling elements rotatably disposed between the outer ring raceway and the inner ring raceway, and [selectively] <u>optionally</u> having a cage for evenly distributing the rolling elements in the rotational direction of the rolling elements between the outer ring raceway and the inner ring raceway, and used under lubrication with a lubricating oil or a grease containing a fluoro-containing polymer or in an atmosphere containing a gas comprising fluorides, wherein

the cage is constituted with a PTFE resin material or a PPS resin material and/or constituted by applying chamfering to inner and outer diametrical sides of the pocket and forming a through hole in the bottom of the pocket.

10. (Amended) A rolling bearing comprising an outer ring having an outer ring raceway, an inner ring having an outer ring raceway and rolling elements rotatably disposed between the outer ring raceway, and the inner ring raceway, and [selectively] <u>optionally</u> having a cage for evenly distributing the

rolling elements in the rotational direction of the rolling elements between the outer ring raceway and the inner ring raceway, and used under lubrication with a lubricating oil or a grease containing a fluoro-containing polymer or in an atmosphere containing a gas comprising fluorides, wherein

the cage is formed with an advanced resin material into a circular shape, and a plurality of pockets each containing the rolling element through an opening and rotatably holding the same are disposed at a predetermined distance in the circumferential direction, the size for the opening of the pocket having a weld line has a value of 93% or more for the diameter of the rolling element, and the size for the opening of at least two other pockets is 80% or more and 93% or less for the diameter of the rolling element and the cage is constituted with a PTFE resin material or a PPS resin material and/or constituted by applying chamfering inner and outer diametrical sides of the pockets and forming a through hole in the bottom of the pocket.

12. (Amended) The rolling bearing as defined in claim 3, wherein at least the rolling element comprises oxide ceramics or has a dense nitride layer on the surface of the rolling element, and the surface roughness of the rolling element, and the surface roughness of the rolling element is 0.005 _m Ra or less and the surface [harness] <u>hardness</u> is Hv 900 or more.

13. (Amended) The rolling bearing as defined in claim 4, wherein at least the rolling element comprises oxide ceramics or has a dense nitride layer on the surface of the rolling element, and the surface roughness of the rolling

element, and the surface roughness of the rolling element is 0.005 μm Ra or less and the surface [harness] <u>hardness</u> is Hv 900 or more.

14. (Amended) The rolling bearing as defined in claim 11, wherein at least the rolling element comprises oxide ceramics or has a dense nitride layer on the surface of the rolling element, and the surface roughness of the rolling element, and the surface roughness of the rolling element is 0.005 _m Ra or less and the surface [harness] <u>hardness</u> is Hv 900 or more.--